CHAPTER D.9
PROJECT DESIGN AND CONSTRUCTION TEMPLATES

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9.1 Summary

In this section, basic barrier island templates are discussed. Dimensions (height, width) for the design and construction of Louisiana barrier islands are recommended. These dimensions are based on engineering, geological, and ecological principles and practices; experiences learned from past projects; and restoration goals.

9.2 Introduction

The two basic templates for the restoration of barrier islands are the construction template and the design template.

- Design template. Design templates should address the primary restoration goal of each island. For example, when infrastructure protection is a primary goal (e.g. Grand Isle and possibly Caminada-Moreau Headland), higher dunes that limit or prevent overwash and combinations of fill and structures may be appropriate. When the main purpose is to maintain barrier islands as a first line of defense against storms and waves for backbarrier environments (and landward cities), the island's geographical position (north or south) is not important. Consequently, a lower and wider island with dune and marsh features may be the appropriate design template. Such a template would use the minimum design cross-section and initial fill to accomplish the design goal. The design template is controlled by natural subaerial and submerged slopes and total volume; natural slopes are not designed but they can be recognized and reproduced.
- Construction template. The construction template is the cross-section that the contractor builds. The construction template should contain sufficient volume to support the design template, taking into consideration short-term equilibration constructability, dewatering, consolidation, slope adjustments, and long-term changes

(renourishment cycles of five to 20 years). Common features of the construction template include:

a. advanced fill in the construction template in addition to the design fill volume to compensate for losses that will occur before the next renourishment;

b. appropriate heights and widths for dunes and marshes so that basic design slopes and elevations are obtained after initial equilibration (about one year). The construction template and the initial equilibrated template will be wider and higher than the design profile, since they contain advanced fill (see Figure D.9-2).

c. a configuration that facilitates proper construction at lower costs. Diking may be needed, for example, to achieve design heights for dunes and construction grades in the marsh.

Illustration of design versus construction templates are shown in Figures D.9-1 and 2 for different design concepts and approaches. In Figure D.9-D.9-1, a landward construction with a low (5 ft) template is illustrated. The cross-section in Figure D.9-D.9-1 shows the construction templates with full containment dikes and the subsequent equilibration of the contained fill after dike removal.

Figure D.9-D.9-2 shows the typical components of a barrier island restoration using higher templates and seaward and landward construction where the construction and design (equilibrated) templates and the advanced fill are illustrated. The drawing shows the construction of a higher template anchored on the existing island. Absence of containment dikes will only be possible if material used to build the beach and dunes has low silt content (less than 20%). The marsh fill component uses the existing island as a natural dike and is contained on the bayside end.

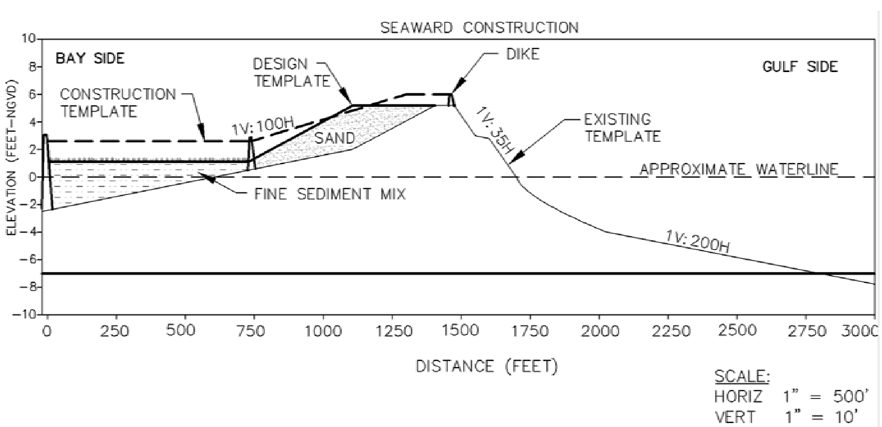

Figure D.9-1. Typical components of a low template and landward construction of a barrier island illustrating equilibration of the contained fill after dike removal.

Most construction templates for Louisiana barrier island restoration contain two basic sediment types: (1) relatively clean sands for dunes and beaches; and (2) sediment mixtures, such as sand, silt, and clay to build backbarrier marsh.

Designers often consider cross-sectional elevations and widths to determine the best way to build barrier islands. The next section address these issues and provides guidance regarding the physical elements that should be included in design templates for the Louisiana barrier island restoration program.

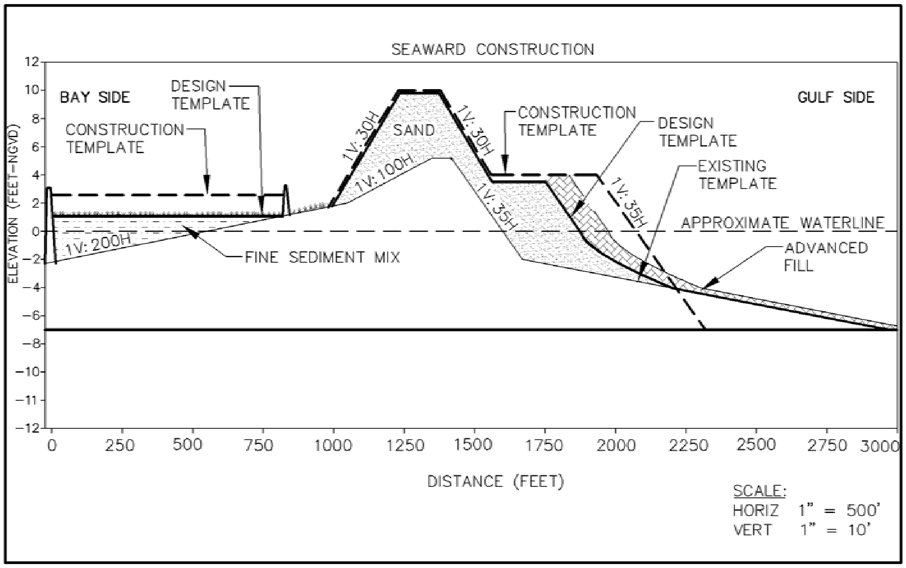

Figure D.9-2. Typical components of a barrier island restoration using higher templates and seaward and landward construction where the construction and design (equilibrated) templates and the advanced fill are illustrated.

9.3 Cross-Shore, Gulf Landward

As this section explains, pilot projects should include construction of dune elevations that range from 5 to 12 feet. These projects should be monitored and their comparative performances assessed. If the priority is creating island area (e.g. acreage per dollar), the optimal template is a wide, low [e.g. 5 feet (1.5 m)] island that provides greater area created per dollar spent. If the priority is to stop island migration and overwash (to protect upland infrastructure), then higher templates [e.g. 10 feet (3 m)] are appropriate. Template maintenance requires that nourishment be an ongoing process, one that is continuously monitored and evaluated. A single construction event will not fulfill the goals of the program.

When considering a construction section, the following design templates have been proposed by the LCA Gulf Shoreline Restoration Team (Table D.9-1).

Table D.9-1. Template options originally considered by the LCA team for the subaerial portion of restored coastal segments

Narrow backbarrier/ marsh and low dunes
Narrow backbarrier/ marsh and high dunes
Wide backbarrier/ marsh and low dunes

As seen from Table D.9-1, the varying components of the proposed templates are backbarrier/marsh width and dune height. These components are discussed in the following sections.

9.3.1 Dune Height and Marsh Platform Width

The basic design should place enough sediment in the island system to produce a volumetrically stable and sediment-rich barrier complex. The islands would then be able to provide better storm protection for backbarrier environments (e.g. wetlands and estuaries). The key parameter in developing an optimal design template is providing enough volume to compensate for the amount of sediment typically lost by the system (e.g. Equation 7 in Chapter 8, “Best Management Practices.”) This planned increase in volume should begin with an initial nourishment that creates a relatively thick, sand-rich dune/beach complex. This configuration should be maintained by periodic nourishment that replaces sands and mixed fine sediments in sufficient quantity.

The initial increase in volume should include natural components of barrier islands (e.g. beach berm/dune/backdune slope and marsh) and bring the island to an effective cross-section that includes dune, beach and marsh area. Effective cross-sections approximate natural conditions that would resist island breaching. Maintenance requirements include: (1) smaller sediment volumes in the beach-dune areas, and (2) reconstruction of marsh area that equals deficits between volume and area loss due to erosion of the bay shoreline and landward migration of beach and dune on top of backbarrier marshes. In this way, basic storm and habitat protection can be provided. The initial fill volume should also include additional sands and mixed fine sediments that are expected to erode from the island between initial construction and maintenance nourishment (i.e. advanced fill, Figure D.9-D.9-2).

Different dune heights have been proposed for the restoration of Louisiana barrier islands. Van Beek and Meyer-Arendt (1982), for example, recommended that constructed dunes need only be about 60 feet (18 m) wide and 4 to 6 feet (1.2 to 1.8 m) in height. These authors suggested that the restored dunes should mesh with adjacent dune systems. Combe and Soileau (1987) report that a dune system built to a height of 11.5 feet (3.5 m) on Grand Isle provided significant storm protection to landward infrastructure. When considering restoration templates for East Timbalier Island, Picciola & Associates (1998) originally suggested three design templates (5, 6, and 7 feet or 1.5, 1.8, and 2.1 m). However, their final conclusions recommended the use of 5 foot (1.5 m) dunes to minimize construction costs. T. Baker and Smith (1997) in the Barrier Island Feasibility Study stated that “higher dunes prevent or limit overwash and protect the integrity of the dune-marsh interface.” Two hypothetical dune elevations, 9 feet (2.7 m) and 6.6 feet (2.0 m), were proposed by these authors. Recently constructed and proposed design elevations range from +5 to +8 feet (1.5 to 2.4 m) (Figure D.9-D.9-3).

There has been extensive discussion in the literature about optimum design templates for the restoration of barrier islands (e.g. Winer 1993; Williams et al. 1992; Van-beek and Meyer Arendt 1982; T. Baker and Smith 1997 and 2001; LCA Science Workshop 2003; Penland 2003). There are two opposing views regarding dune height: (1) restoration projects should build dunes to the same elevation found in existing dunes (e.g. 5 ft.) and let the new dunes overwash; or (2) restoration projects should build dunes higher than present elevations (e.g. 10-12 ft.) to avoid overwash and breaching.

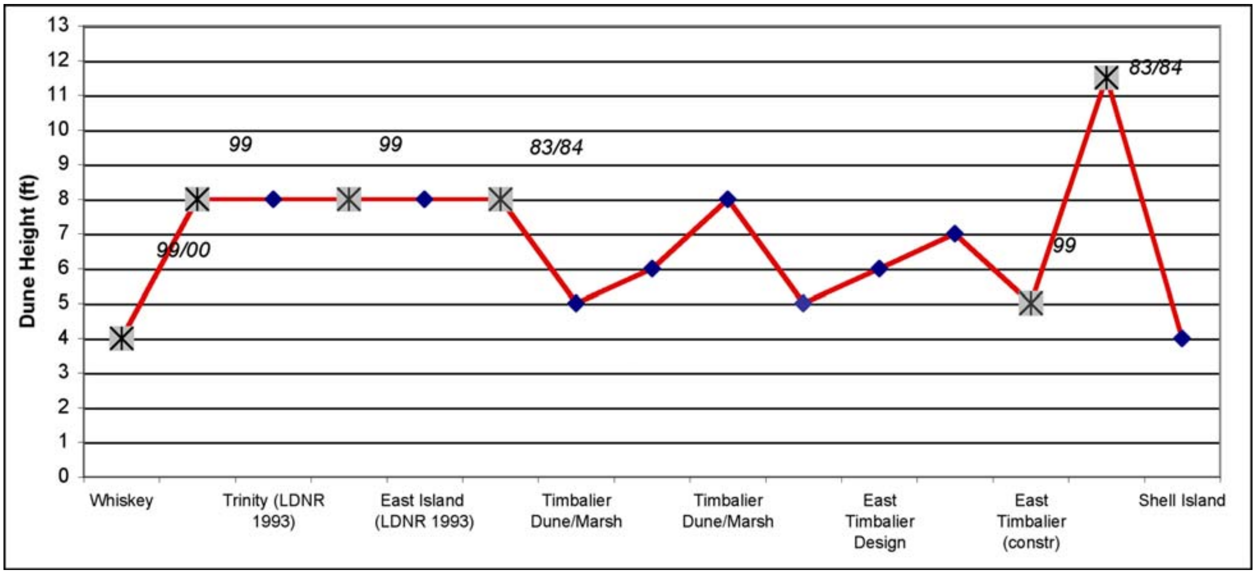

Figure D.9-3. Dune height of recently built and proposed restoration projects in the Louisiana barrier islands. Italicized numbers indicate dates of construction for constructed projects.

Artificially built higher dunes will restrict the number of overwashes and breaches on restored barrier islands. That is why dune height should be a function of the project goals. If the restoration goals are to maintain the shoreline in place to protect infrastructure, higher dunes are needed. If the goals are to maximize island and marsh footprint while maintaining the island area and the integrity of its associated environments, than the most appropriate template would include lower and wider dunes.

As described in the literature (e.g. Dingler and Reis 1991; Penland and Suter 1984), overwash represents a source of sediment supply for backbarrier marshes and thus helps maintain backbarrier marsh elevations. When shoreline erosion is rapid and overwash is too frequent, however, colonization and stabilization of marsh vegetation is limited. A balance should be achieved between the need for beach-dune maintenance requirements and the natural sediment supply requirements of backbarrier marshes. This balance may be initially estimated by measuring natural island templates.

For example, many barrier islands evolve to a point where a 300 ft wide marsh platform is in a state of vertical quasi-equilibrium. In this situation, the overwashed sediments counteract rates of relative sea level rise. Assuming a relative sea level rise of 1 cm/yr (Penland and Ramsey 1990), these marshes are receiving approximately 1 cy/ft/yr (or less due to organic matter accumulation) to maintain equilibrium. Therefore, on higher restored islands where overwash is limited, marsh sediment should be mechanically supplied at a level of 1 cy/ft/yr to maintain vertical elevation. Because marshes accrete vertically (organic matter accumulation) as a response to relative sea-level rise, the actual required volumes to be placed may be less. Monitoring constructed islands is the best tool for improving designs when natural sediment supply to marshes is prohibited due to the construction of higher barrier island templates.

9.3.2 Retreat Mechanisms and Island Height

The barrier islands of Louisiana are a "thin sand cap over a thick mud system" that is responding to rapid relative sea level rise of about 1 cm per year (e.g. Penland and Ramsey 1991). Sand bodies in most cases appear to be confined to beach and dune systems that range from generally +5 foot (1.5 m) elevations in natural barrier systems, and extend to Gulf water depths of -4 to -7 feet (-1.2 to -2.1 m) depth. In some cases, sand may extend to greater depths as reported by Penland et al. (1988) for the Grand Isle and Caminada-Moreau headland area. Below the sandy zone, there is a larger mud-dominated profile that extends 30,000 to 50,000 feet (9,100 to 5,200 m) offshore. This larger profile probably represents the active zone for mud profiles and is either convex for recently abandoned or accretionary deltaic systems or concave in older transgressive (erosive) systems (Mehta 2002; Kirby 2002).

An extraordinary characteristic of the barrier island system in Louisiana is the extreme rate of past retreat. These rates are an order of magnitude greater than any other barrier island system in the Gulf of the Mexico. Williams et al. (1992) has reported average retreat rates ranging from 30 to 60 feet per year for several Louisiana barrier islands.

Various mechanisms are responsible for these retreat rates. One of the driving mechanisms, given the rapid increases in relative sea level (RSL) and the flat muddy profiles of the Louisiana coast, is the cross-shore equilibration of the mud/sand profile to relative sea level rise. Campbell and Benedet (2003) using data published by Williams et al. (1992) and List et al. (1997) have found significant correlations between rates of measured island retreat and measured profile slope. It is hypothesized that even though the system retreats in response to relative sea level rise, island configuration is maintained and held in place for a period of time by the sand cap in the subaerial and nearshore region. Recent data (Penland 2003) has shown that as the barrier islands become sand starved, retreat rates accelerate significantly. In this setting, severe storms are the triggering mechanisms that drive the island landward as it readjusts in response to temporal disequilibrium in the nearshore environment. Although mud profiles react to storms using different physical processes than sand systems (e.g. Mehta 2002), the concave shape of the mature transgressive system may have similar long-term responses to sea-level rise, with large adjustments during major storms. These retreats last long enough to expose, liquefy, and erode the once semi-compacted mud face of the active profile.

Describing long-term equilibration of sand systems, Brunn (1988) identified a mass balance that predicts the landward shift of the barrier island system. This method uses nearshore sediments to create a new landward barrier system and nourish the offshore profile in response to relative sea level. According to the Brunn Rule, during the movement of sediments offshore, there is conservation of volume to a depth of closure (Doc). In the Louisiana sand-mud system, it is difficult to identify the depth of closure for the cross-shore process of the finer sediment fraction (Doc-m). This difficulty arises because major redistribution of muds in response to relative sea level rise occurs during liquefaction of hardened mud bottoms (Mehta 2002) (Figure D.9-D.9-4). Most fluidized muds move offshore as gravity flows, but a smaller portion moves landward in response to wind and wave driven currents (Mehta 2002).

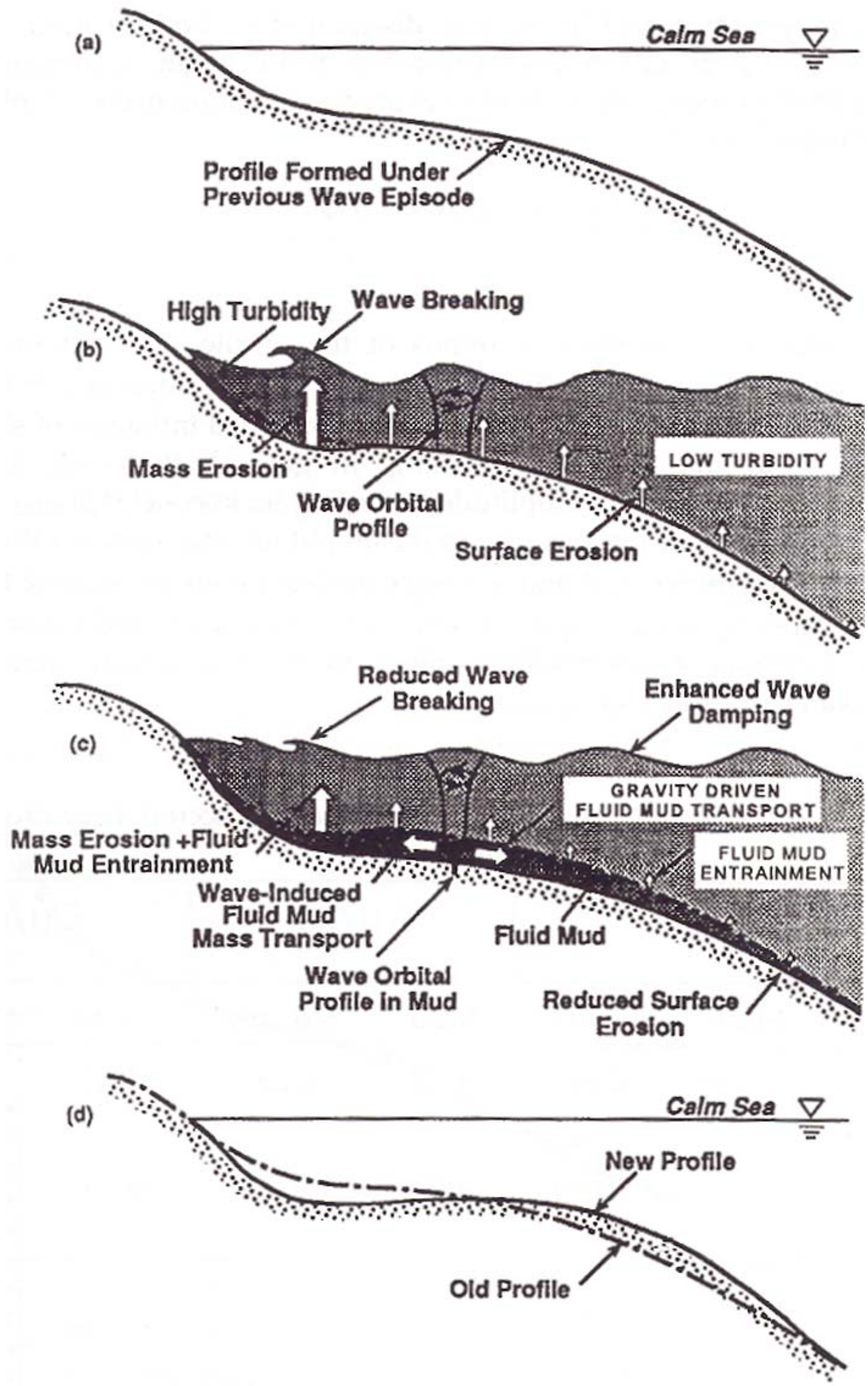

Figure D.9-4. Illustration of mud profile response to a wave episode (after Mehta 2002).

It can be inferred that the elevation and amount of sand in the barrier island will determine the threshold storm that can overwash the island and expose underlying muds. With higher elevations, say + 10 to 12 feet (3 to 5 m) and substantial volumes of sand, most overwash events could be avoided, and the barrier island system would transition from a mud-sand system to a sand-dominated system. With higher dune elevations, however, muds would no longer be eroded from the active profile to overwash and nourish the backbarrier marshes.

Lower island configurations tend to overwash frequently, thereby providing natural cohesive and non-cohesive sediment nourishment to marsh areas. Lower islands, [e.g. 5-6 feet (1.5 to 1.8 m)], will tend to create more marsh in intertidal areas for the initial dollar investment. However, frequent and severe overwash will inhibit the establishment of marsh vegetation, as discussed previously. To avoid excessive overwash, it is suggested that the range of elevations for lower restoration templates fluctuates between 5 and 6.5 ft. Many of the processes relevant to island dimensions still need to be further quantified as part of the adaptive management and monitoring programs proposed in the LCA Study. Template refinement requires that nourishment be an ongoing process that is continuously monitored and evaluated, and projects with elevations that range from 5 to 10 feet should have their comparative long-term performance assessed. The procedure is not a single construction event but a comprehensive program.

9.3.3 Marsh Platform

Marsh platforms should be constructed at elevations that will satisfactorily perform in the intertidal zone until the next renourishment. This goal requires that the initial construction be high enough to accommodate compaction and dewatering of the fine sediment mixture (sand, silt, clay), so that the design marsh elevations will be intertidal and able to maintain healthy marsh systems for the design lifetime. Although marsh platform width depends on project goals, previously constructed backbarrier fills that were intended to be colonized by marsh vegetation ranged from 300 to 750 feet wide. Construction techniques should be applied when considering marsh restoration that introduce sediments.

9.4 Cross-Shore, Gulf Seaward

This section discusses the restoration of barrier islands using natural protective features such as coastal sand dunes and berms. The section also presents guidance for defining the water depth that should be considered for the design of restoration projects (known as closure depth).

When considering a gulf-seaward cross-section, the following design templates have been proposed by the LCA Gulf Shoreline Restoration Team (Table D.9-2). The variable components of the proposed design templates' (shallow vs. deep closure depth and presence-absence of dunes) are discussed in the following items.

Table D.9-2. Design template options originally considered by the LCA team for th subaerial portion of restore coastal segments

With dunes/shallow closure depth
With dune/ deep closure depth
Without dunes/ shallow closure depth
Without dunes/ deep closure depth

9.4.1 Presence or Absence of Dunes

Dunes are fundamental components of barrier island systems and should be viewed as a valuable natural resource (e.g. Figures D.9-5 and 6). Dunes store sand and provide a buffer against storm waves and coastal setup (Figure D.9-5). Dunes are important aspects of barrier island restoration as well; their presence reduces frequent overwashes and breaches, therefore helping to maintain the integrity of barrier islands (e.g. Figures D.9-6 and 7).

The project cross-section should include horizontal space for the dune if one is to be included. Due to lack of space, dunes may not be feasible in some locations (e.g. some segments of the Chenier Plain). In the vicinities of Peveto and Holly Beaches, for example, it is more appropriate to construct a template with a wider beach berm and advanced fill than a dune. Dunes should be constructed on the barrier island systems of Terrebone, Barataria, and Plaquemines (and Chandeleurs if they are considered for restoration), following dimension considerations discussed in previous sections. Other design alternatives, such as the construction of wider beach berms, may be applicable to the Chenier shoreline.

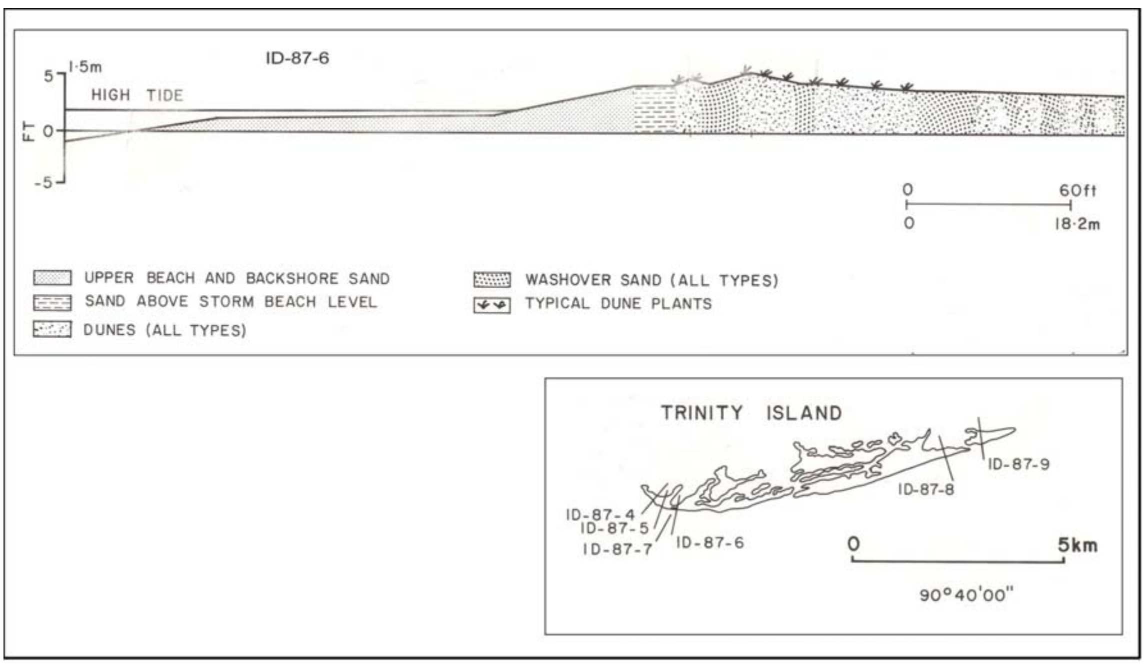

Figure D.9-5. Cross-sectional profile located on the western flank of Trinity Island illustrating a relatively low (about 6 ft) protective dune, profile measured by Ritchie et al. (1989). Note the presence of a 30 ft beach berm seaward of the dune crest.

Figure D.9-6. Protective dunes artificially built at Grand Isle. The dunes were built at higher elevations to avoid overwash and sheet flow across the island and to serve as a storm buffer that would protect island infrastructure.

9.4.2 Presence or Absence of Beach Berm

Subaerial beaches occur on coasts whenever there is sufficient sediment for the waves to re-work and deposit it in shallow depths and above the mean sea level. A common cross-shore profile of the backshore or subaerial beach shows recognizably distinct landforms. The beach berm is a relatively flat platform, accretionary in nature and common to most beaches. The berm results from the accumulation of sediments on the landward boundary of wave influence (e.g. Figures D.9-7 and 8), usually with a landward sloping surface (Short 1999; Komar 1997). The berm is the landward most morphological feature that interacts constantly with incoming waves, and its location in healthy beaches (sediment rich) marks the transitional zone where hydrodynamic sediment transport mechanisms cease and Aeolian transport (dunes) dominates (e.g. Short 1999; Carter 1988; Komar 1997). During storm attack, the beach berm serves as a buffer zone that protects landward environments (e.g. dunes and marshes) from the direct attack of waves. Berms also serve as a temporary sand source for the formation of protective features (sand bars) during storms, which spurs island recovery during subsequent calmer wave periods (e.g. Figure D.9-8).

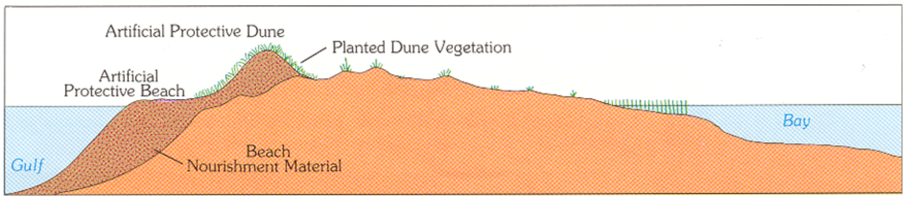

Figure D.9-7. Hypothetical non-dimensional diagram illustrating the concept of artificial protective dunes and berms.

Figure D.9-8. Storm recovery berm verified on Grand Terre Island (picture taken on 07/08/2003) showing onshore-offshore transport of sand.

In Louisiana, many beaches are deprived of well developed berms, due to characteristic sand starvation. Exceptions to this trend are islands that contain greater sand volumes, such as the eastern side of the Caminada-Moreau Headland (Figure D.9-9), and the restored Grand Isle. Other barrier islands have remnants of berms (usually 10-40 ft) in some segments (e.g. Figure D.9-5).

From a restoration perspective, where significant sand volumes will be placed along the Gulf shoreline, it is important to recognize the beneficial effects of berms. Because they function as storm protection features, berms should be part of the design template for the restoration of the Louisiana barrier islands. A well developed berm between the high water line and the dune system will provide significant protection to dunes and backbarrier marshes. The dunes will experience less wave attack during storms and consequently will be less eroded/scarped and overwashed. Resulting benefits include favoring the establishment of dune and marsh vegetation and preservation of these valuable environments for greater periods of time.

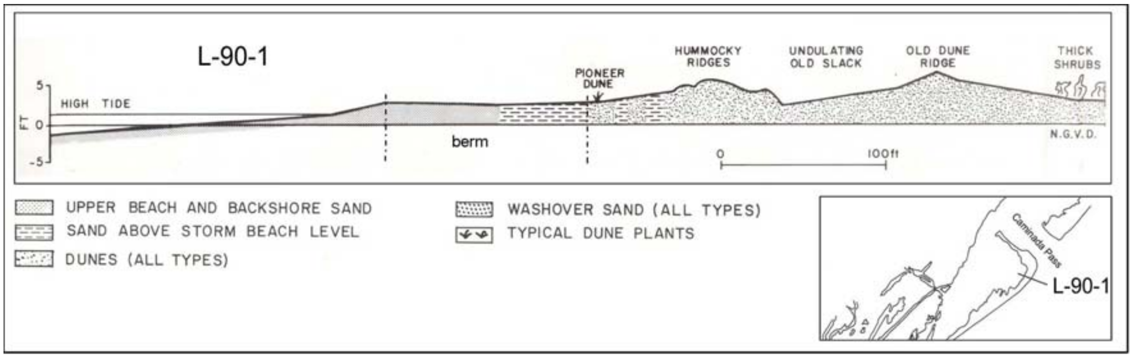

Figure D.9-9. Cross-section profile of the submerged segment of the eastern flank of Caminada-Moreau Headland (the Caminada Spit).

Nourishment projects should have enough volume to maintain a protective berm in front of the dune system. A barrier island restoration template that included a protective berm feature is shown in Figure D.9-2.

9.4.3 Shallow Versus Deep Depth of Closure (D_{oc})

Previous reports have used predictive relationships or measured historical beach profiles to define the D_{oc} offshore Louisiana's barrier islands. These reports, while using the predictive relationships to determine D_{oc}, have not considered wave bottom friction over the extremely wide and relatively flat shelf, wave damping by fluidized muds, or differentiation between sand and mud depth of closure. Recently CPE proposed other indicators of the Doc for sandy sediments (D_{oc-s}) in Louisiana (CPE 2001; CPE 2003). Four alternative methods for determining the depth of closure in Louisiana are presented. These methods include:

- mapping the offshore limit of sand distribution
- determining the offshore "slope break" in the profile
- determining the point of intersection between sand equilibrium profiles and measured profiles
- using approximations based on predictive relationships fed by shallow water wave statistics.

These methods return shallower sand depth D_{oc-s} (sand depth of closure) for the Louisiana chenier and barrier island systems (between 4 and 8 feet).